MINERALOGICAL CHARACTERISTICS OF COAL IN VARIOUS CLEANING CIRCUITS

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The optimum utilization of our national coal resources while still affording the protection of our environment can not be achieved without beneficiation. However, our most common ways of measuring the success or failure of beneficiation processes are not truly representative and may well be responsible for unnecessary economic and energy resource losses. This is the result of several factors, the most important of which are:

1. The analyses which we perform do not really measure the materials which are being beneficiated. Rather, they are indirect measurements.

One of the most common quality criteria is that of ash. However, we do not remove ash from coal during beneficiation processes; we really change distribution of the minerals or rock consist of the coal material, and thereby change the "ash" as measured. Also, we do not remove sulfur as such, we remove sulfur containing minerals such as pyrite, marcasite, etc.

2. Mineral properties, not elemental properties, are what effect combustion and beneficiation processes up until the time when the minerals are broken down; yet it is the elemental composition which we seem to be most concerned about.

Seemingly obvious, this point is often overlooked in all stages of beneficiation and utilization until major problems occur. Two coals may have the same SiO_2 content when analyzed, but the physical properties of quartz (sand) are quite different from those of clays (illite, kaolinite, etc.). Different minerals, even of similar compositions, require different cleaning processes and have different effects upon process equipment.

3. Common analytical methods, because they destroy the mineralogical structures, give the impression that coals are to a large extent homogeneous and consistent in mineral content. This impression is markedly false and often leads to major false assumptions.

The two most obvious, i.e. most studied, examples of this error are the forms of sulfur and the siliceous contents of coal. Conventional analyses will give the same silica content for a carbonaceous shale as for a calcareous one, but they will react quite differently during beneficiation and combustion. Total sulfur is the most common analysis for this element of environmental concern, but occasionally a "sulfur breadown" analysis will be performed. Although knowing whether the sulfur is "pyritic", "organic" or "sulfate" is helpful; it is not enough. Knowing that the sulfur is predominately "pyritic" is insufficient, we must know other factors such as size, distribution within the coal matrix, and whether the particles are attached to the coal material as well as the degree of liberation. All these factors affect the beneficiation processes.

Physical beneficiation is generally considered to be a "mature" subject in that most changes which have occurred over the past few years have been in terms of equipment design or the order in which particular operations are performed. These operations are generally based on physical characteristics such as specific gravity or hardness and brittleness difference between the minerals of interest and the coaly materials. However, these processes are still measured on element reduction basés rather than one of specific mineral concentration or reduction.

Froth flotation, considered a higher lever of sophistication in beneficiation, is also based on differences in mineralogical properties. Based upon particle surface characteristics it tends to be more chemical than physical in nature. Tendencies of particles to be hydrophilic or hydrophobic in nature are enhanced through the use of chemical additives and then a physical separation is made.

The next level of sophistication in coal beneficiation will most likely be that of chemical coal cleaning. It will also be the most costly level, especially when the large tonnage amounts involved in coal utilization are considered. In order to keep these costs to a minimum, while still attaining desired results, process operations will have to be carefully planned and closely monitored. Process designers will have to know exactly what minerals will be involved and in what amounts. Acquiring a better knowledge of what minerals occur in specific coals and how they are affected by less expensive physical beneficiation is an obvious first step.

As part of a much larger effort by the U. S. Department of Energy, the Coal Research Bureau of the College of Mineral and Energy Resources at West Virginia University has been characterizing the mineralogy and petrography of three major bituminous coals in an effort to determine whether the mineralogical associations can be closely followed through common physical beneficiation processes. A listing of the minerals commonly present in these coals is provided in Table 1. Also included are the chemical formulas with the elements of most interest to the beneficiation plant operator underlined. This listing is based upon bituminous coals as most sub-bituminous coals and lignites meet current emission specifications and are not cleaned to a large extent.

Mineralogical analyses were performed using a number of different techniques including x-ray powder diffraction analysis, infrared spectroscopy, normative calculations, and optical petrography. All met with limited success although each had limitations as to the number of minerals which could be identified or accurately quantified. X-ray powder diffraction proved to be the most versatile as to accuracy, ease of implementation and number of different minerals identified versus misidentifications. Mineralogical sink-float (washability) curves were prepared (Figure 1) and compared with actual equipment operations (Table 2). It can be seen, that their predicted value varied for specific minerals and specific processes. However, the indication is that further effort in this area is justified and that a strong potential exists for tracing of specific mineral assemblages through the beneficiation processes and that these processes may be more efficiently designed and monitored. Such monitoring in the future could lead to multi-stream, multi-product plants with only a minimum amount of coal being subjected to more intensive cleaning processes. With careful planning, such a plant could provide a maximum fuel yield while providing maximum environmental protection at a minimum cost.

TABLE 1

MINERALS OF THE DISTRICT #3 PITTSBURGH COAL.
SYMBOLS INDICATE ANALYTICAL PROCEDURES AVAILABLE FOR EACH MINERAL AND WHETHER THE PROCEDURE CAN BE USED FOR QUANTITATIVE, SEMIQUANTITATIVE, OR QUALITATIVE MINERAL ANALYSIS.

	X-ray Powder Diffraction	*Infrared Spectroscopy*	*Normative Calculations*	*Optical Petrography*	*Scanning Electron Microscopy*	*Formulae*
ILLITE	S		Q	S	I	variable
KAOLINITE	Q	Q	Q	S	I	$Al_4(Si_4O_{10})(OH)_8$
QUARTZ	Q		Q	S	I	SiO_2
FELDSPARS	S				I	variable
MUSCOVITE				S	I	$KAl_4(AlSi_3O_{10})(OH)_2$
CARBONATES		Q		S		variable
CALCITE	Q	Q	S	I	I	$CaCO_3$
DOLOMITE	Q		S	I	I	$CaMg(CO_3)_2$
BASSANITE	S				I	$CaSO_4 \cdot \frac{1}{2}H_2O$
GYPSUM		I		I		$CaSO_4 \cdot 2H_2O$
IRON DISULFIDES	Q		Q	S	I	FeS_2
PYRITE				S		FeS_2
MARCASITE				S		FeS_2
APATITE	S				I	$Ca_5(F,Cl,OH)(PO_4)_3$
HEMATITE				S		Fe_2O_3
RUTILE				S	I	TiO_2

Q = Quantitative determinations (±10%)

S = Semiquantitative determinations (±10-30%)

I = Identification only possible

TABLE 2

Mineral weights in the products of the commercial preparation plant and the pilot plant scale coal cleaning equipment. Actual mineral weights are compared to weights predicted from the mineral washability curves of the Pittsburgh coal.

	Deister Table 3/16" X 100M		"Baum" Jig 1" X 3/16"		WEMCO HMS Drum Separator 2" x 10M		Heavy Media Cyclone 10 X 100M	
	Actual	Curve	Actual	Curve	Actual	Curve	Actual	Curve
YIELD	85%	83%	71%	93%	89%	85%	94%	95%
S.G.	?	1.35	?	>1.80	?	1.38	?	>1.80
ASH	5.9%	5.9%	7.7%	7.7%	6.2%	6.2%	8.4%	8.4%
M.M.	126#	120#	133#	185#	138#	135#	183#	210#
ILLITE	16#	29#	28#	46#	55#	31#	6#	58#
KAOLINITE	34#	30#	29#	38#	39#	31#	32#	41#
QUARTZ	21#	20#	25#	30#	23#	22#	26#	34#
CALCITE	13#	4#	12#	8#	10#	4#	9#	12#
PYRITE	30#	23#	28#	36#	0#	26#	36#	44#

= pounds of the mineral in the cleaned coal when one short tone of feed coal is cleaned.

M.M. = mineral matter.

S.G. = specific gravity of the washing medium.

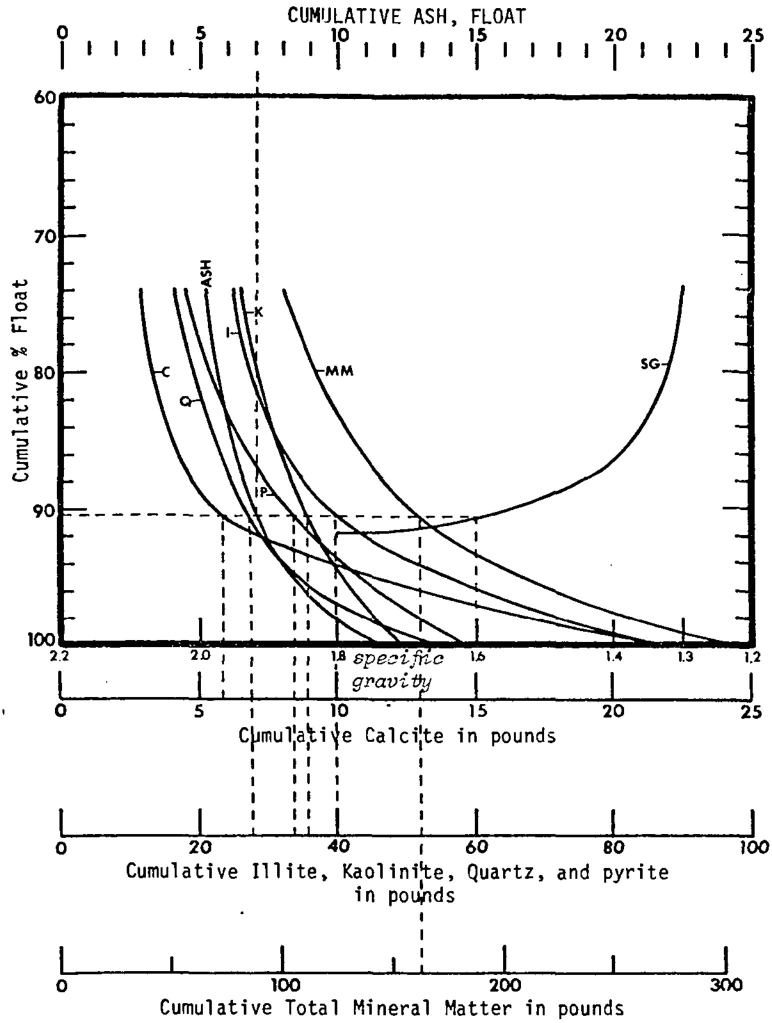

FIGURE 1

Washability curves for the minerals in the District 3 Pittsburgh coal (See the footnote on the next page for explanations of this diagram).